Impacts of Atmosphere-Ocean Coupling on Southern Hemisphere Climate Change

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1. Introduction

Climate in the Southern Hemisphere (SH) has undergone significant changes in recent decades. These changes are closely linked to a shift of the Southern Annular Mode (SAM) towards its positive polarity, which is driven primarily by Antarctic ozone depletion. There is growing evidence that ozone depletion and the shift of the SAM have large impacts on Southern Ocean circulation change. However, it is poorly understood whether and how ocean feedback might impact the SAM, ozone depletion, and climate change in the SH atmosphere.

The purpose of this study is to identify the impacts of atmosphere-ocean coupling on the variability and long-term changes of the SH atmosphere. We conduct and compare simulations of the recent past (1960-2010) using the Goddard Earth Observing System Chemistry Climate Model (GEOSCCM) with and without an interactive ocean.

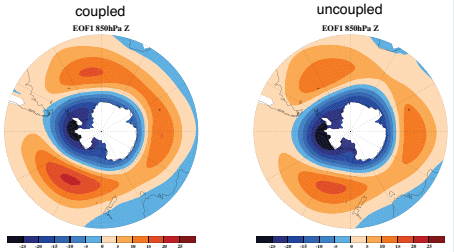
2. GEOSCCM and Simulations

- **GEOSCCM** couples the GEOS-5 AGCM with comprehensive atmospheric chemistry packages. It was evaluated in CCMVal-2 and was found to have a realistic representation of stratospheric chemistry, transport, and dynamics.
- **GEOS-AOCCM** is the coupled ocean version of the GEOSCCM. It couples the GEOSCCM with the GFDL Modular Ocean Model (MOM4) and the Los Alamos sea ice model (CICE).

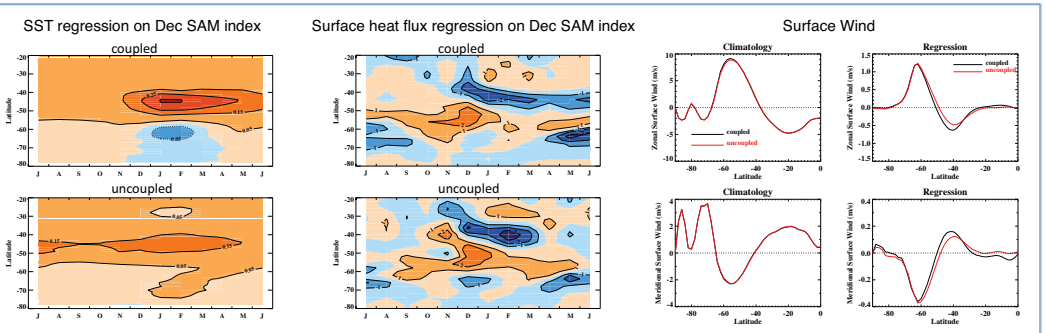
Two transient simulations (1960-2010) were conducted:

- **Coupled**: A GEOS-AOCCM run. It uses CCMVal REF1 scenario of GHGs and ODSs. The model produces a realistic QBO. The atmospheric model has a horizontal resolution of 2° latitude by 2.5° longitude. The ocean model is run at a resolution of about 1° by 1°.
- **Uncoupled**: A GEOSCCM run. It is the same as the Coupled run, except that the sea surface temperatures (SSTs) and sea ice concentrations are taken from the Coupled run.

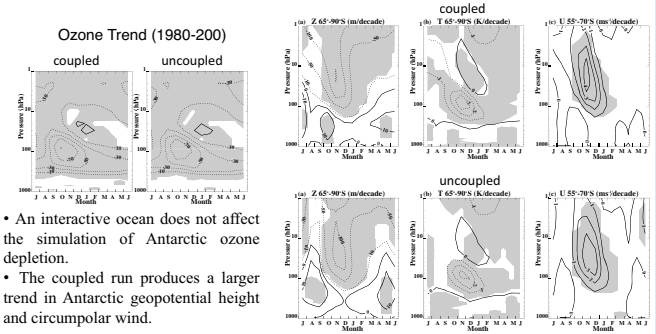
3. Results



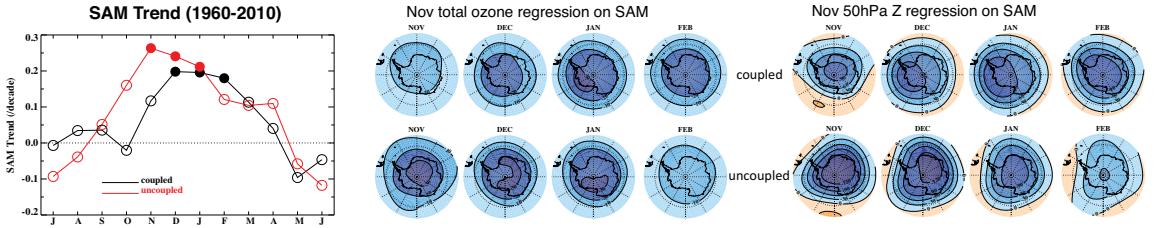
- The SAM pattern is well simulated by both models.
- The PC of 850 hPa geopotential height EOF 1 is used as SAM index.



- The coupled run captures the SST responses to the SAM.
- The SAM variability of surface heat flux persists longer in the coupled run.
- The climatology is nearly identical in the two runs.
- The coupled run has larger SAM variability at midlatitudes.



- An interactive ocean does not affect the simulation of Antarctic ozone depletion.
- The coupled run produces a larger trend in Antarctic geopotential height and circumpolar wind.



- The coupled run simulates statistically significant SAM trend during DJF, one month later than in the uncoupled run.
- The stratospheric SAM variability peaks in DJF in the coupled run, one month later than in the uncoupled run.

4. Summary

- Preliminary results from the coupled and uncoupled ocean version of the GEOSCCM show that ocean feedback affects the seasonality of the SAM trend.
- Atmosphere-ocean coupling also impacts the timing of the peak stratospheric SAM variability.
- Atmosphere-ocean coupling does not impact simulation of Antarctic ozone depletion.
- More ensemble simulations are needed in order to determine the robustness of these results.